1961

Facilities for instruction and research on fluid mechanics and hydraulics, 1961

J. B. Herbich

FRITZ ENGINEERING LABORATORY

HYDRAULICS DIVISION

Memorandum No. M-23

447

FACILITIES FOR INSTRUCTION AND RESEARCH

In

FLUID MECHANICS and HYDRAULICS

Prepared by

John B. Herbich

March 1961

Bethlehem, Pennsylvania

F.L. Report No. 237.16-M-23

C O N T E N T S

1. INTRODUCTION

Instruction and research in hydraulics at Lehigh University dates from 1887, when the first American college hydraulics laboratory was erected on the Lehigh campus. It was here that Professor Mansfield Merriman conducted his important pioneer research work.

The Fritz Engineering Laboratory was built in 1909, and was extensively modernized and expanded in recent years. Since 1955, it has served as the headquarters of the Department of Civil Engineering, housing the staffs and laboratories of the various divisions of the Department - including the Hydraulics Division.

The Hydraulics Division provides a comprehensive range of courses of instruction in Fluid Mechanics, Hydraulics, and related topics, at undergraduate and graduate levels. With the present student and staff members, considerable energy can be devoted to research and project investigations for private industry and Governmental bodies. These activities provide the stimulation of industrial practice, essential to staff and students, and assist in the dissemination of recent theoretical developments in fluid mechanics and hydraulics to industry.

The Division is able to draw, where necessary, on the scientific and technical resources of other Divisions of the Department, in particular those specializing in Soil Mechanics and Sanitary Engineering, as well as the Instrumentation Specialists, Machinists and Mechanics of the Department's Laboratory

Operations Group. In addition, the cooperation of members, and the use of facilities of other Departments of the University are readily available.

The following pages provide details of the facilities and work of the Hydraulics Division.

2. GENERAL LABORATORY DETAILS

The Hydraulics Laboratory occupies an area of more than 6000 square feet, conveniently placed on three levels. Some 4000 square feet of this space are used for research and investigational work. The floor plan is shown in Fig. 1 and 2.

The recirculating water supply system has a capacity of 8 cubic feet per second at 60 feet head, and 4 cubic feet per second at 130 feet head, the power being supplied by two centrifugal pumps - one 8-inch and one 6-inch. Pressure can be controlled by means of either a 300 cubic feet elevated constant-head tank, or a 300 cubic feet constant pressure tank.

Calibration and flow measurement facilities include twin-volumetric tanks, each of 400 cubic feet capacity, together with a wide variety of calibrated Venturi meters, weirs, flow nozzles, and a 4-inch magnetic flow meter.

The main pipe systems are 10 inches and 8 inches in diameter, and, by means of valves and provisions for connections, great flexibility is available for the ready installation of equipment for research and test work.

Electric power is available at 210-volt, 600 amp AC, 3-phase, through bus ducts, and at 240-volt DC up to 60 HP.

3. RESEARCH FACILITIES

(1) Channels and Flumes

(i) Wave Channel (Fig. 3). The main wave channel is 3 feet wide, 2 feet deep, and 67 feet long, excluding the end sections. It is of steel and aluminum frame construction, and is glass-walled over its full length.

The wave generator is of the pendulum type, with provision for variation of wave amplitude and frequency. The upstream wave absorber consists of inclined layers of perforated aluminum plate, while the downstream absorber has perforated plates on a 15° impermeable sloping beach.

Two carriages span the channel, running on rails supported independent of the channel. Each carriage carries capacitive-type wave probes, and a two-channel Sanborn recorder, as well as Brush recorders, are available for recording purposes.

(ii) Glass-Walled Flume (Fig. 4). This flume has a horizontal test section which is 24 feet long, 18 inches wide, and 30 inches deep. The bed, which is above floor level, is of glass and aluminum sections, any of which can be removed or adjusted in height. The entrance sluice gate can maintain a 6 feet head, and the flow rate can be varied up to 4 cubic feet per second. Flow measurement is effected with a calibrated Venturi meter.

(iii) Tilting Flume. The adjustable tilting flume is 40 feet long, 12 inches wide, and 18 inches deep. Its slope can be varied to a maximum of 1 in 20, and flow rates up to 4 cubic feet per second are possible. The depth of flow is regulated by a pressure-type sluice gate, and the flow is measured with a calibrated Venturi meter.

(2) Tanks

(i) Multipurpose Tank (Fig. 5). This tank has a test section 35 feet long, 10 feet wide, and 2 feet deep, excluding entrance and discharge section. The water level is regulated by means of a screw-driven tail-gate, and the flow is measured by means of a calibrated Venturi meter.

Flow rates up to 6 cubic feet per second are available. This tank can be used for three-dimensional flow studies, sediment transportation research, or for wave investigations.

(ii) Spillway Tank. The model spillway test tank has a test section 35 feet long, 10 feet wide, and 2 feet deep. The entrance box is 4 feet long, 4 feet deep, and 10 feet wide, and being separate from the main multi-purpose tank, can be removed up to 10 feet from it, and rotated in a horizontal plane up to 90°.

Head differentials up to 10 feet are obtainable, and flow measurement is effected either by Venturi meters or volumetric tanks. The normal capacity of 4 cubic feet per second can be increased, if necessary, to 6 cubic feet per second.

(3) Sediment Pipe Circuit (Fig.6 & 7). The test-circuit for tests on the pumping of sediment-water mixtures consists of a 280 cubic feet tank and a 6-inch pipe line, with a centrifugal dredge pump powered by a calibrated 40 HP direct current motor. The pump speed can be varied between 1100 and 2400 revolutions per minute, and the flow rate, which is measured by a magnetic flow meter, can be varied up to 1200 gallons per minute. Flows with sediment concentrations up to 25 per cent by volume, have been tested in this installation with pumps up to 10-1/2-inch impeller diameter in size.

(4) Wind Tunnel. The wind tunnel unit has a 12-inch diameter closed test section, and maintains air speeds up to 75 feet per second to within 0.3 feet per second.

(5) High Pressure Pump Unit. This pump, driven by a 50 HP A.C. motor, develops pressures up to 5000 lb per sq in. for high pressure test purposes.

(6) Oil Recirculating Unit (Fig.8). Oil flows from 50 to 2000 gallons per minute can be established in this unit, which has six 100-gallon storage tanks which can be used individually or in combination. Flow measurement facilities include two orifice meters and a Venturi meter.

4. INSTRUCTIONAL FACILITIES.

The following installations and equipment, although designed primarily for instructional purposes, are in many cases adaptable to research and investigational studies.

(1) Viscosity Measuring Equipment. These items include Saybolt (Fig.9) and Ostwald-Fenske viscometers and temperature baths.

(2) Flow-Measuring Equipment (Fig.10). A 4-inch pipe and channel circuit contains a series of flow-measuring devices including an orifice, an elbow, a Venturi meter, and a flow nozzle, in the pipe section, and a weir and Parshall flume in the channel section.

(3) Manometry Stand (Fig.11). This unit provides facilities for the demonstration of various types of manometers.

(4) Pipe Friction Units (Fig.12, 13 & 14). Two pipe friction test units are available for instructional purposes. An oil-recirculation type (Fig.12) is used primarily for laminar flow studies, and a water-recirculation type (Fig. 13 & 14) for turbulent flow studies.

(5) Smoke Tunnel. This unit has a test section measuring 20 inches long, 11 inches high, and 1-1/2 inches deep, approximately, the air speed range being from 1-1/2 to 8 feet per second.

(6) Hele-Shaw Unit. This free surface Hele-Shaw table has a working area 4 feet by 2 feet, for the demonstration of two-dimensional flow patterns past various boundary forms.

(7) Magnus Effect Unit. Demonstrations of the Magnus effect can be given with this unit, in which fluid flows past a rotating cylinder.

(8) Turbine Test Stand. The test-loop for turbine testing consists of a constant pressure tank, a pump, water dynamometer, and Venturi meter for flow measurement (Fig.15).

A smaller test-loop for an impulse-turbine consists of a pump, a Prony brake, and an orifice meter for flow measurement (Fig.16).

(9) Force of Jet Apparatus (Fig.17). The unit provides means for verifying the impulse-momentum equation, as well as determining the coefficients of velocity.

(10) Cavitation Unit (Fig.18). Demonstration of cavitation in a plexiglas test section can be given.

5. UNDERGRADUATE AND GRADUATE COURSES

The outlines of the undergraduate and graduate courses offered by the Hydraulics Division are given in Appendix A.

6. REPORTS AND STAFF PUBLICATIONS

Staff publications and reports of the Division are listed in Appendices B and C, respectively. Project reports are available on loan, subject to the approval of the organizations which sponsored the investigations.

7. ACKNOWLEDGMENT

The report was written by John B. Herbich, Associate Professor and Chairman of the Hydraulics Division. Mr. R. Kozo prepared the drawings, and Miss E.E. Young typed the manuscript. The writer would like to acknowledge the assistance of H.R. Vallentine, Associate Professor, in preparation of this report, and the encouragement received from Professor W.J. Eney, Head of the Civil Engineering Department and Fritz Engineering Laboratory. Professor L.S. Beedle is the Director of the Laboratory.

* * * * *

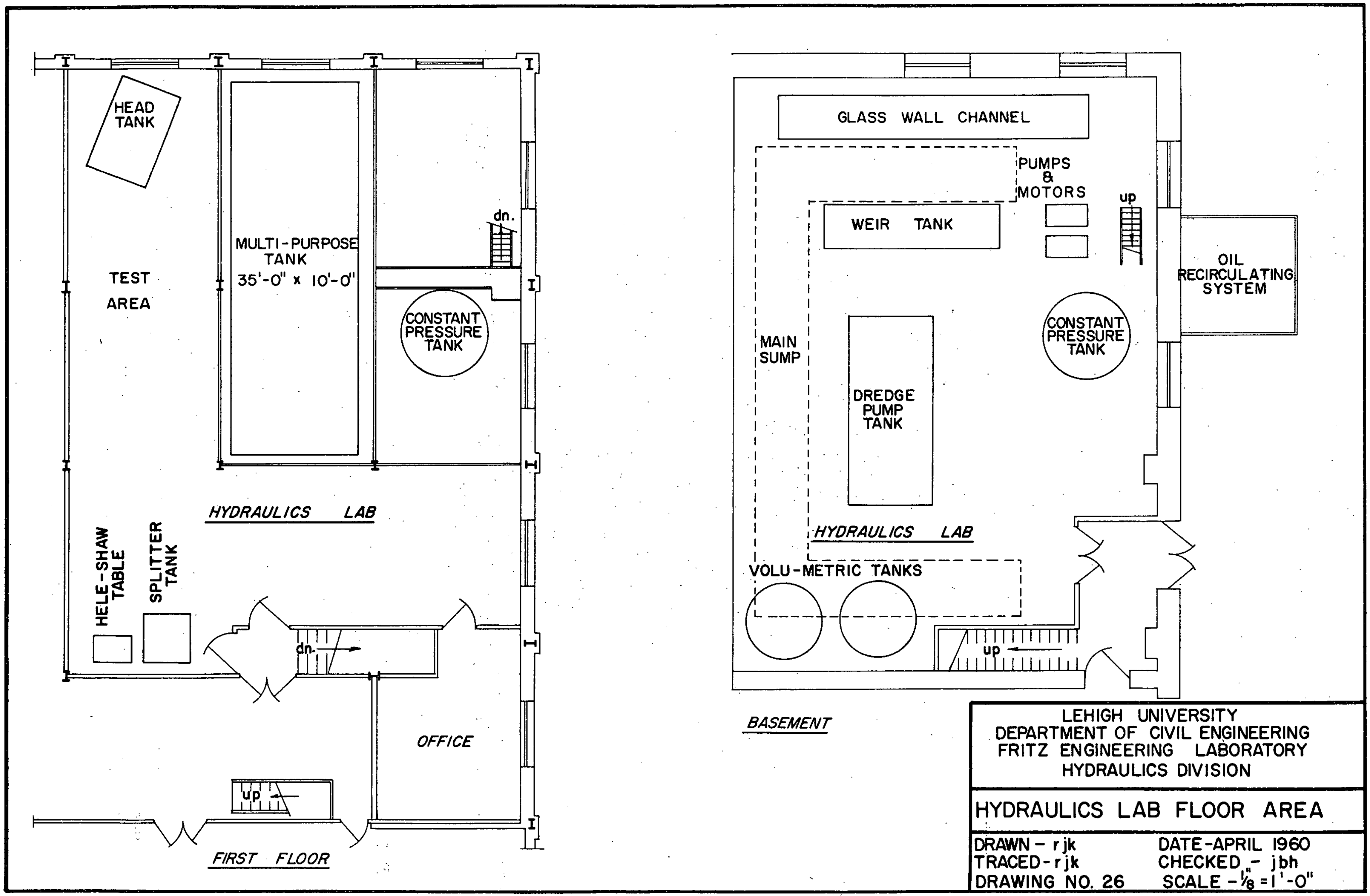

HEAD TANK
MULTI-PURPOSE TANK 35'-0" x 10'-0"
TEST AREA
dn.
CONSTANT PRESSURE TANK
HYDRAULICS LAB
HELE-SHAW TABLE
SPLITTER TANK
dn.
OFFICE
up
FIRST FLOOR
GLASS WALL CHANNEL
PUMPS & MOTORS
up
WEIR TANK
OIL RECIRCULATING SYSTEM
MAIN SUMP
CONSTANT PRESSURE TANK
DREDGE PUMP TANK
HYDRAULICS LAB
VOLU-METRIC TANKS
up
BASEMENT
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
HYDRAULICS LAB FLOOR AREA
DRAWN – rjk
TRACED – rjk
DRAWING NO. 26
DATE – APRIL 1960
CHECKED – jbh
SCALE – 1/8" = 1'-0"

Fig. 1

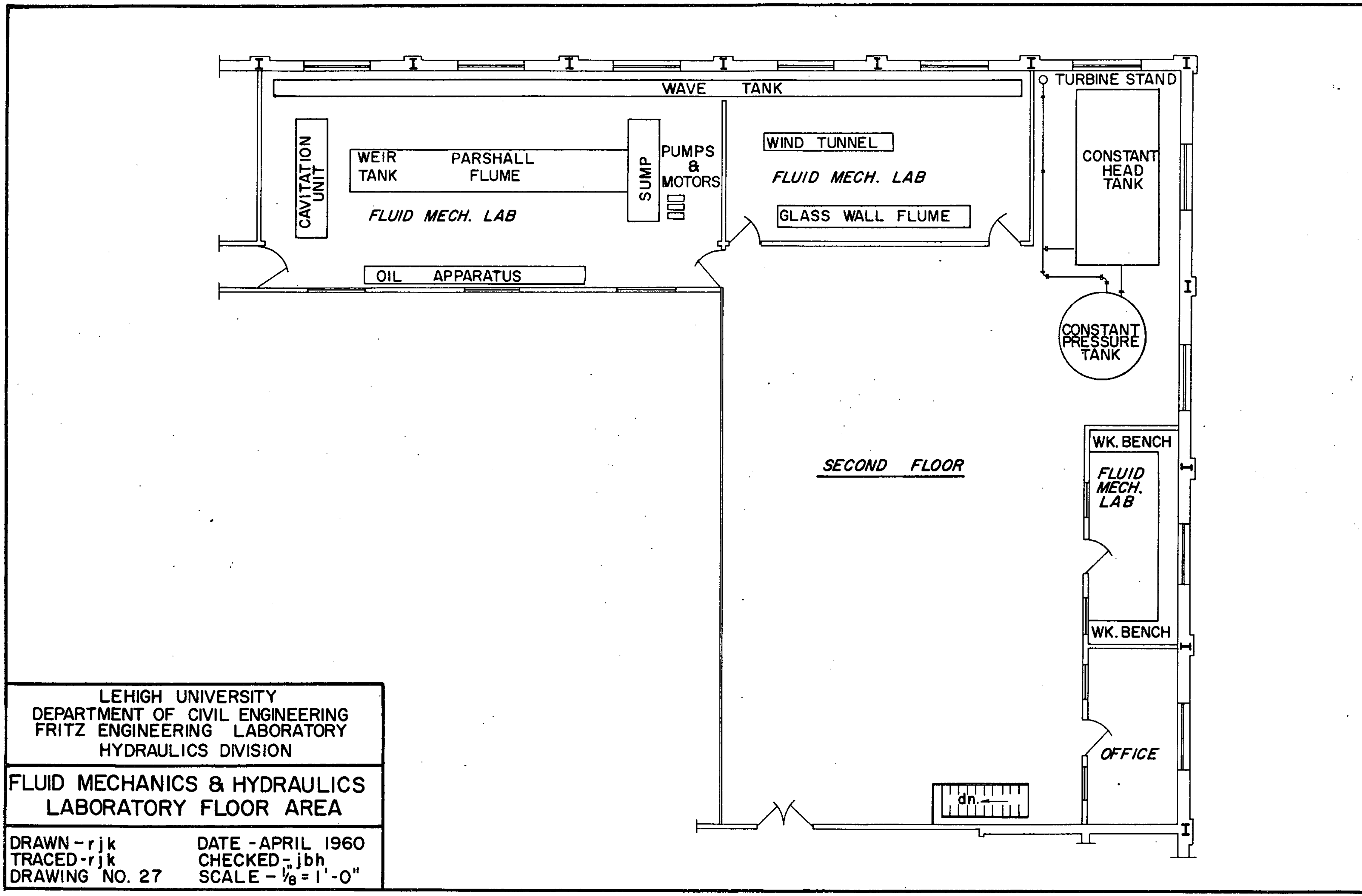

WAVE TANK
TURBINE STAND
CAVITATION UNIT
WEIR TANK
PARSHALL FLUME
SUMP
PUMPS & MOTORS
WIND TUNNEL
FLUID MECH. LAB
FLUID MECH. LAB
GLASS WALL FLUME
CONSTANT HEAD TANK
OIL APPARATUS
CONSTANT PRESSURE TANK
SECOND FLOOR
WK. BENCH
FLUID MECH. LAB
WK. BENCH
OFFICE
dn.
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
FLUID MECHANICS & HYDRAULICS
LABORATORY FLOOR AREA
DRAWN - rjk
TRACED - rjk
DRAWING NO. 27
DATE - APRIL 1960
CHECKED - jbh
SCALE - 1/8" = 1'-0"

Fig. 2

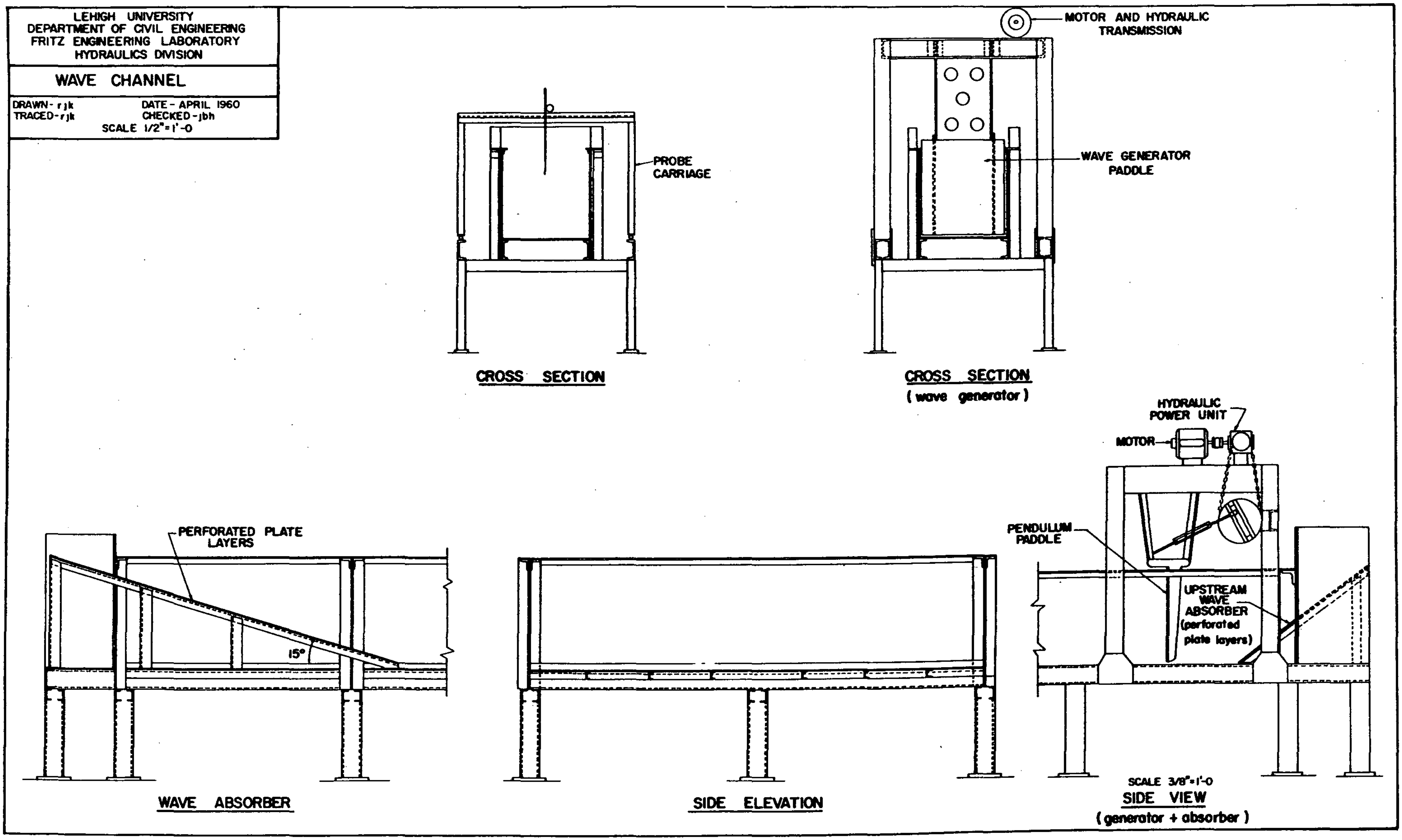

LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
WAVE CHANNEL
DRAWN - rjk
TRACED - rjk
DATE - APRIL 1960
CHECKED - jbh
SCALE 1/2" = 1'-0
PROBE CARRIAGE
CROSS SECTION
MOTOR AND HYDRAULIC TRANSMISSION
WAVE GENERATOR PADDLE
CROSS SECTION
(wave generator)
HYDRAULIC POWER UNIT
MOTOR
PENDULUM PADDLE
UPSTREAM WAVE ABSORBER
(perforated plate layers)
PERFORATED PLATE LAYERS
15°
WAVE ABSORBER
SIDE ELEVATION
SCALE 3/8" = 1'-0
SIDE VIEW
(generator + absorber)

Fig.3

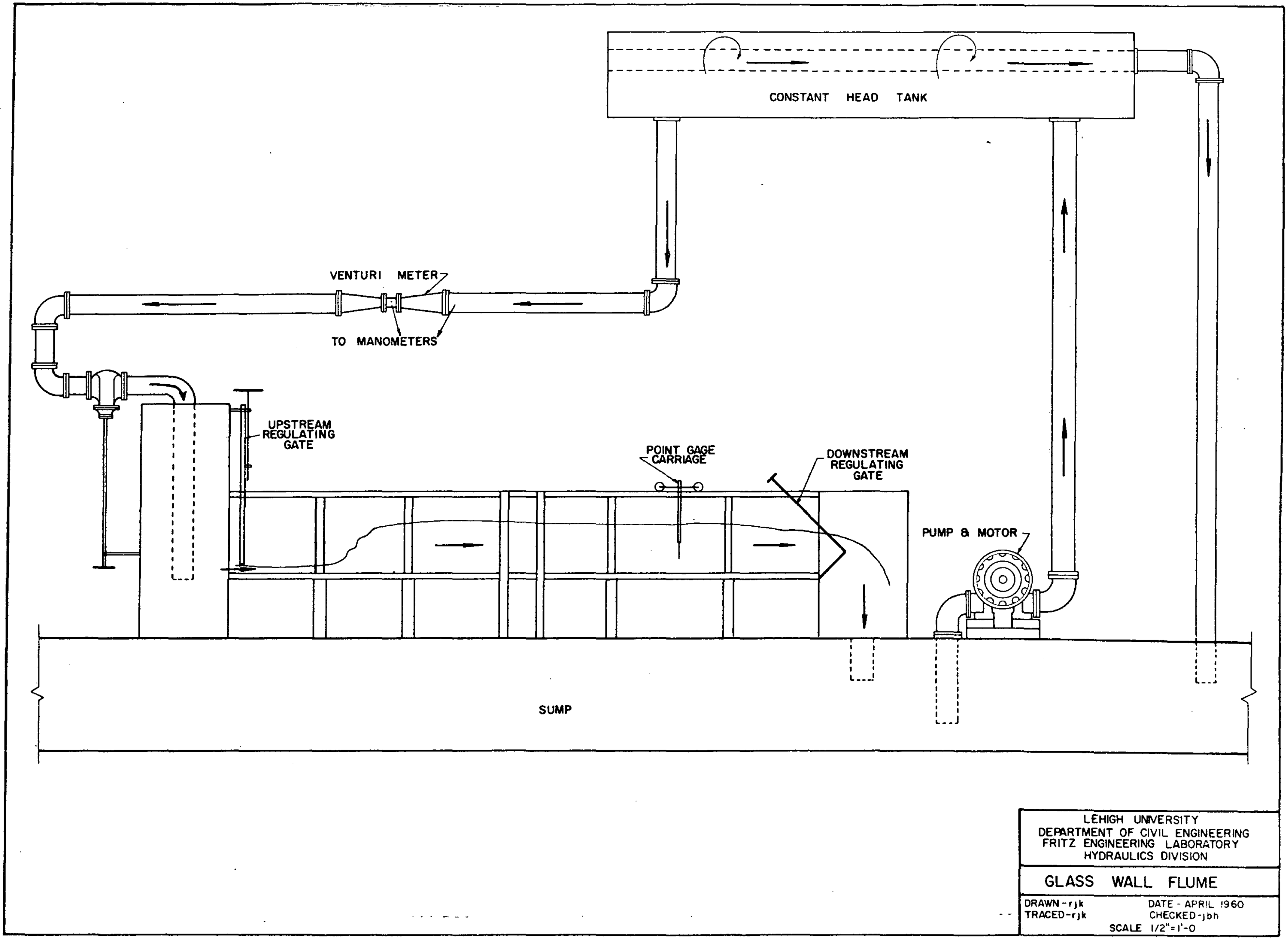
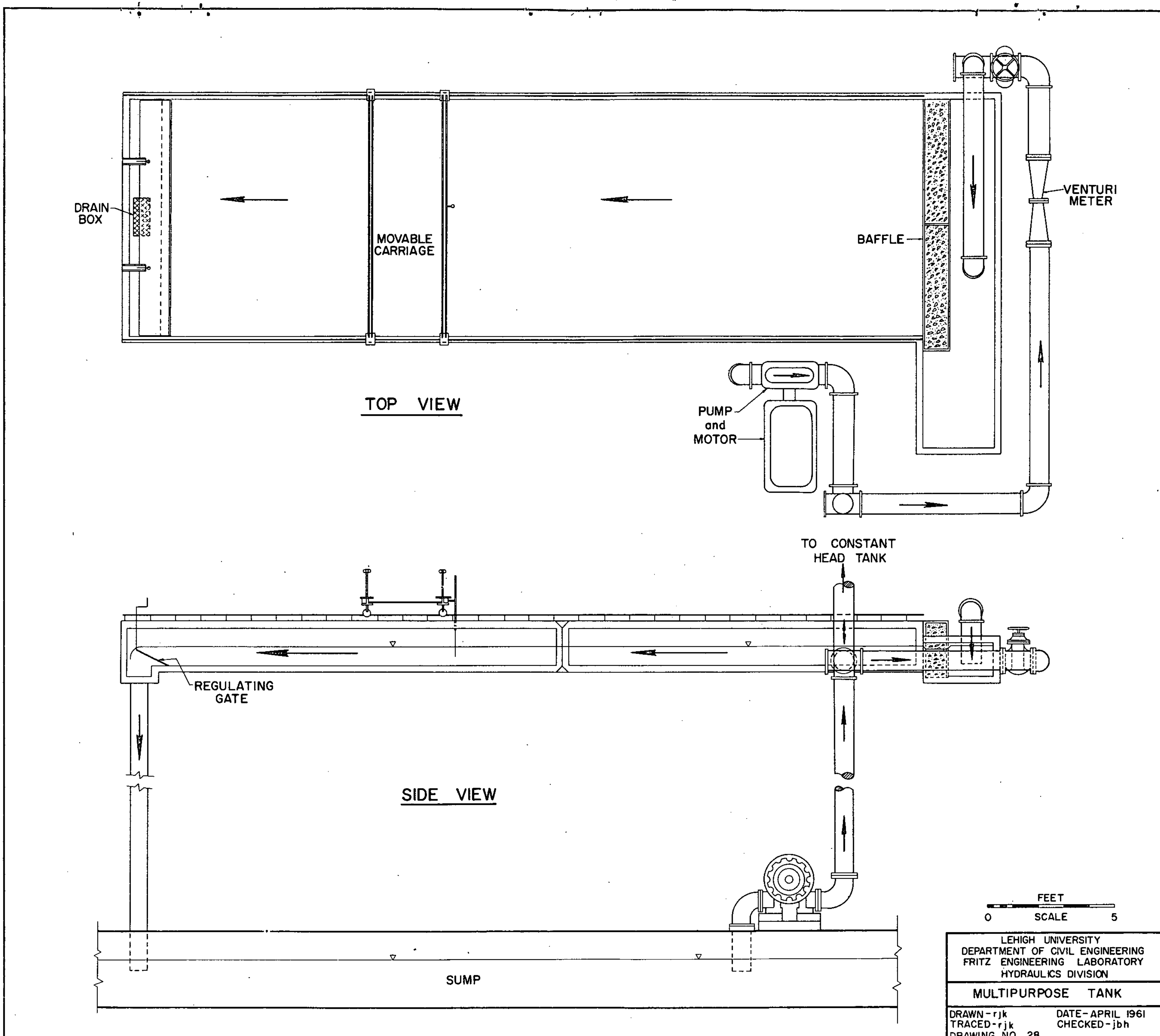

CONSTANT HEAD TANK
VENTURI METER
TO MANOMETERS
UPSTREAM REGULATING GATE
POINT GAGE CARRIAGE
DOWNSTREAM REGULATING GATE
PUMP & MOTOR
SUMP
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
GLASS WALL FLUME
DRAWN - rjk
TRACED - rjk
DATE - APRIL 1960
CHECKED - jbh
SCALE 1/2"=1'-0

Fig.4


DRAIN BOX
MOVABLE CARRIAGE
BAFFLE
VENTURI METER
PUMP and MOTOR
TOP VIEW
TO CONSTANT HEAD TANK
REGULATING GATE
SIDE VIEW
SUMP
FEET
0 SCALE 5
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
MULTIPURPOSE TANK
DRAWN - rjk
TRACED - rjk
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DATE - APRIL 1961
CHECKED - jbh

Fig. 5

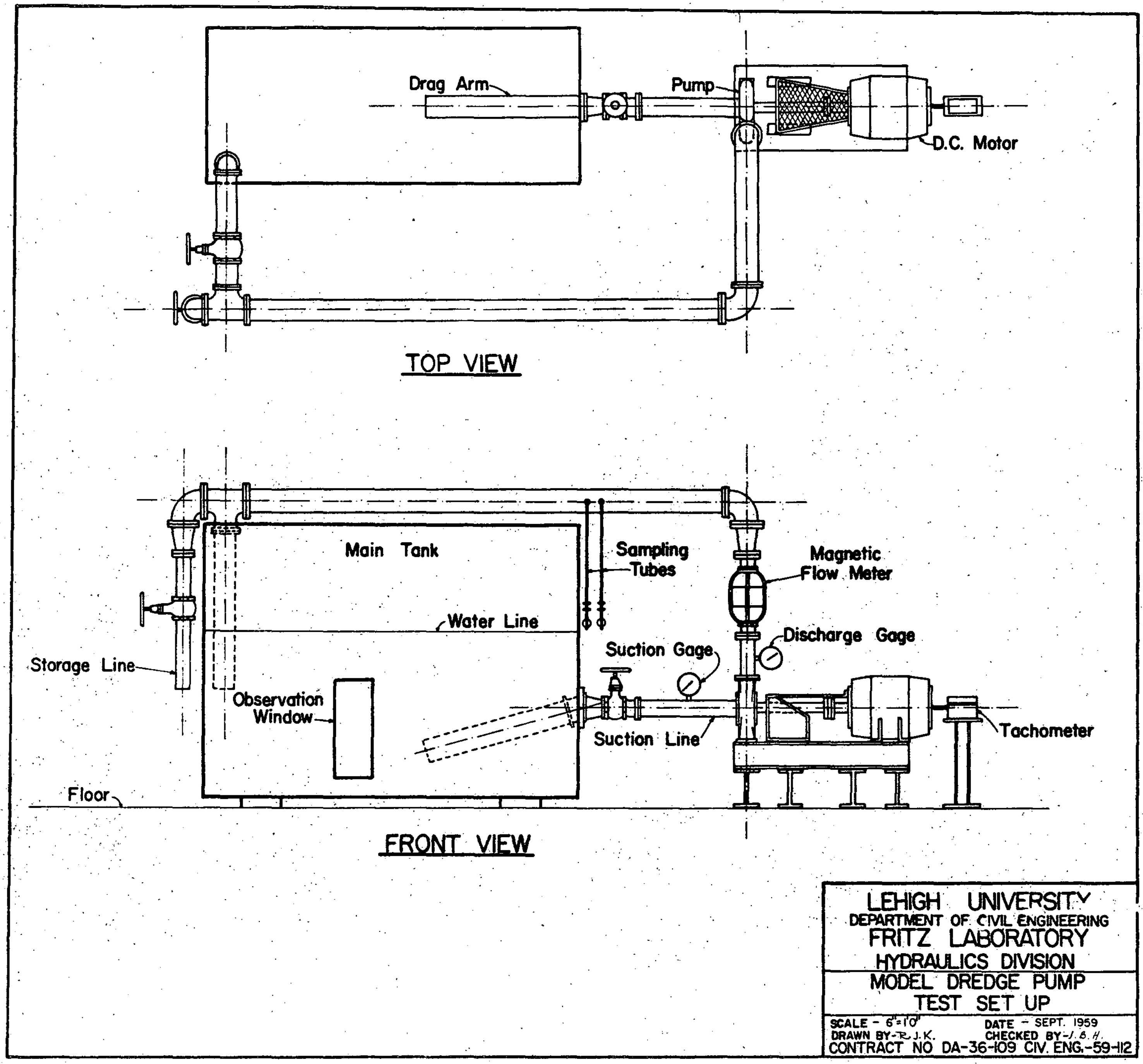

Drag Arm
Pump
D.C. Motor
TOP VIEW
Main Tank
Sampling Tubes
Magnetic Flow Meter
Water Line
Discharge Gage
Suction Gage
Storage Line
Observation Window
Suction Line
Tachometer
Floor
FRONT VIEW
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ LABORATORY
HYDRAULICS DIVISION
MODEL DREDGE PUMP
TEST SET UP
SCALE - 6"=1'0"
DATE - SEPT. 1959
DRAWN BY-R. J.K.
CHECKED BY-J. B. H.
CONTRACT NO DA-36-109 CIV. ENG.-59-112

Fig. 6

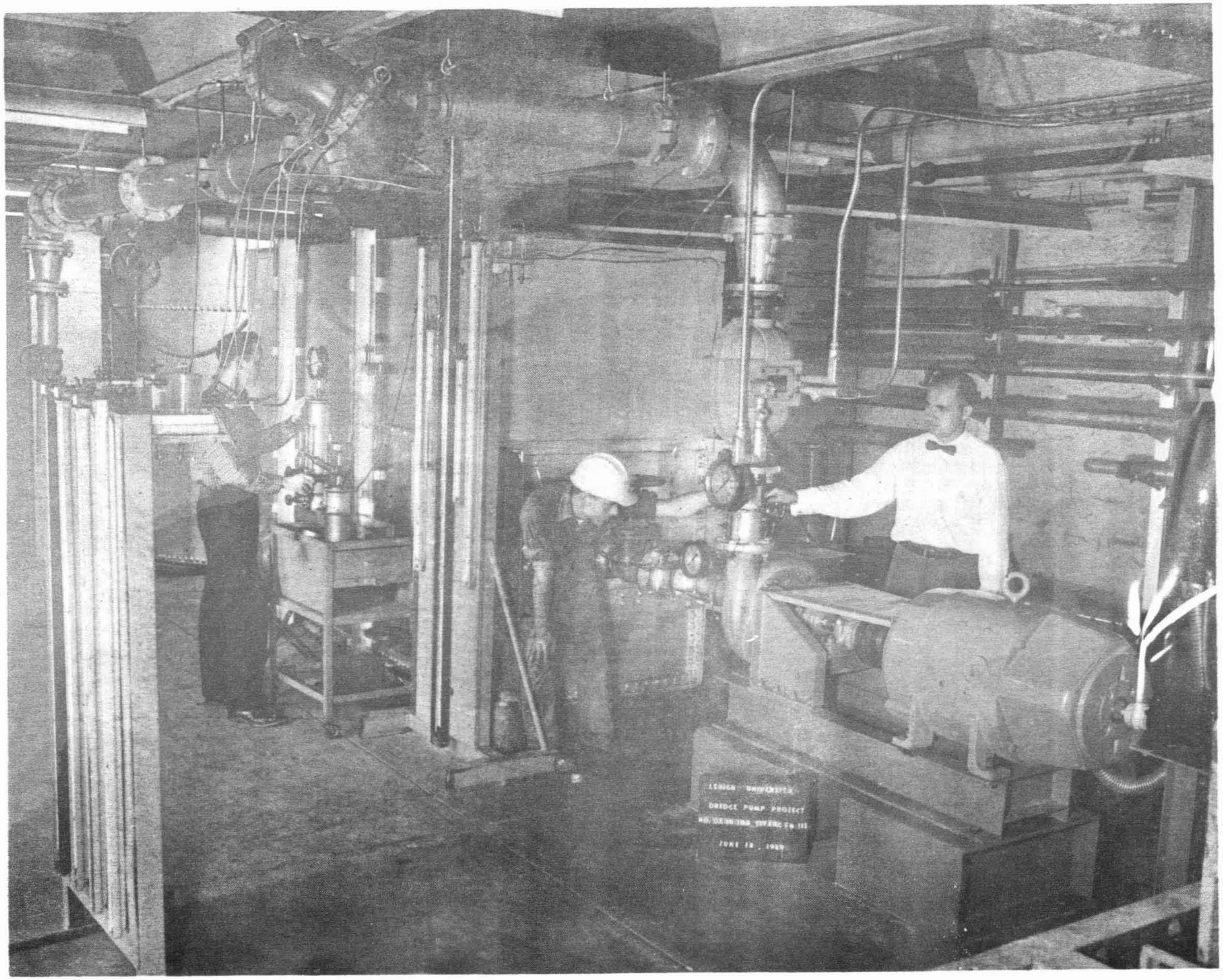
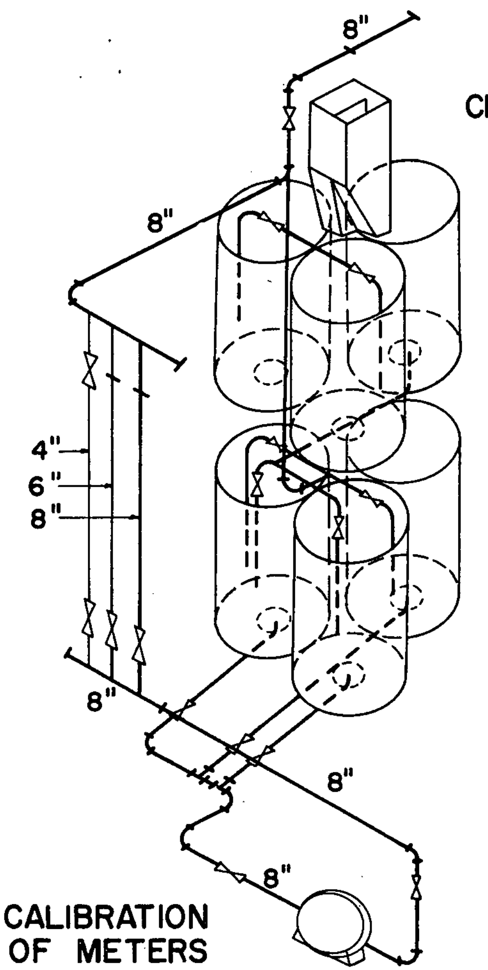


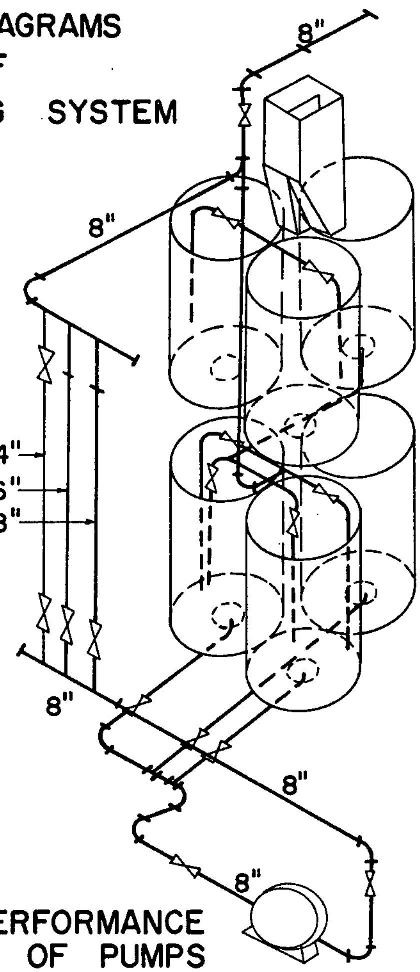
FIG. A-1. General View of Test Facility.

Fig. 7

FLOW DIAGRAMS
OF
CIRCULATING SYSTEM



A.) CALIBRATION
OF METERS



B.) PERFORMANCE
OF PUMPS

LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION

OIL RECIRCULATING SYSTEM

DRAWN - rjk	DATE-APRIL 1960
TRACED-rjk	CHECKED - jbh
DRAWING NO. 25	SCALE -

Fig. 8

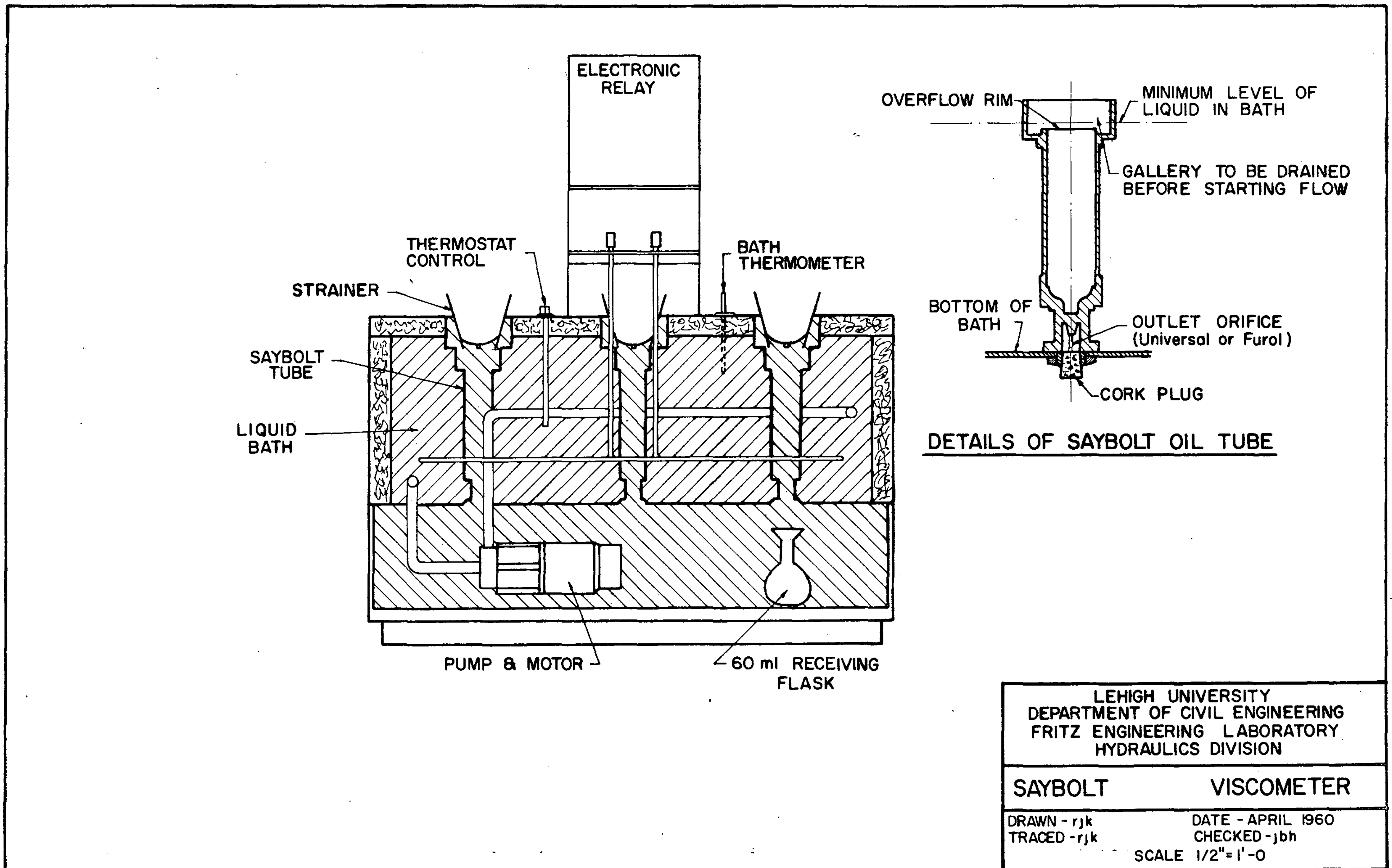

ELECTRONIC RELAY
THERMOSTAT CONTROL
BATH THERMOMETER
STRAINER
SAYBOLT TUBE
LIQUID BATH
PUMP & MOTOR
60 ml RECEIVING FLASK
OVERFLOW RIM
MINIMUM LEVEL OF LIQUID IN BATH
GALLERY TO BE DRAINED BEFORE STARTING FLOW
BOTTOM OF BATH
OUTLET ORIFICE (Universal or Furol)
CORK PLUG
DETAILS OF SAYBOLT OIL TUBE
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
SAYBOLT VISCOMETER
DRAWN - rjk
TRACED - rjk
DATE - APRIL 1960
CHECKED - jbh
SCALE 1/2"=1'-0

Fig. 9

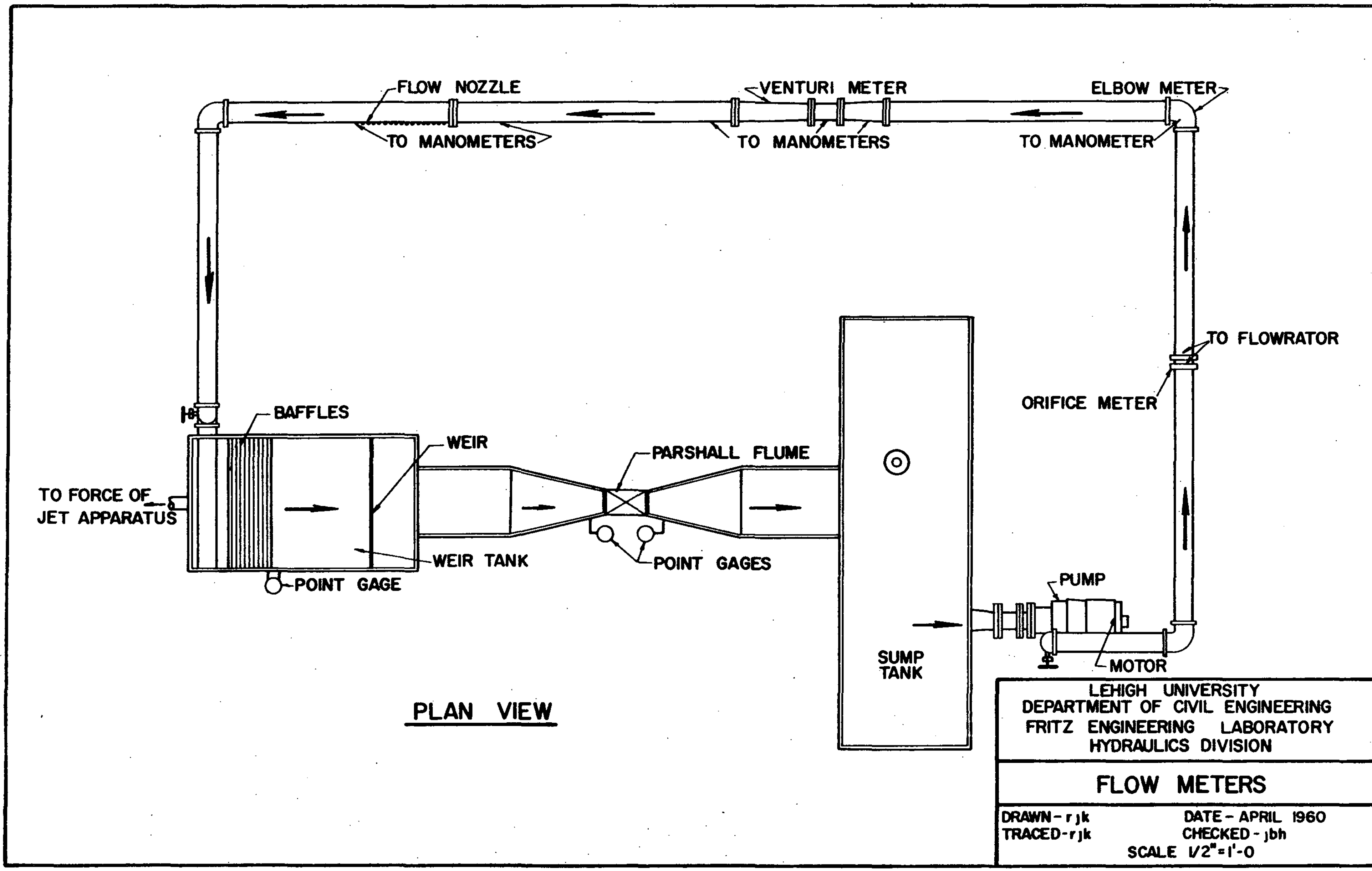

FLOW NOZZLE
VENTURI METER
ELBOW METER
TO MANOMETERS
TO MANOMETERS
TO MANOMETER
TO FLOWRATOR
ORIFICE METER
BAFFLES
WEIR
PARSHALL FLUME
TO FORCE OF JET APPARATUS
WEIR TANK
POINT GAGES
POINT GAGE
PUMP
MOTOR
SUMP TANK
PLAN VIEW
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
FLOW METERS
DRAWN - rjk
TRACED - rjk
DATE - APRIL 1960
CHECKED - jbh
SCALE 1/2"=1'-0

Figure 10

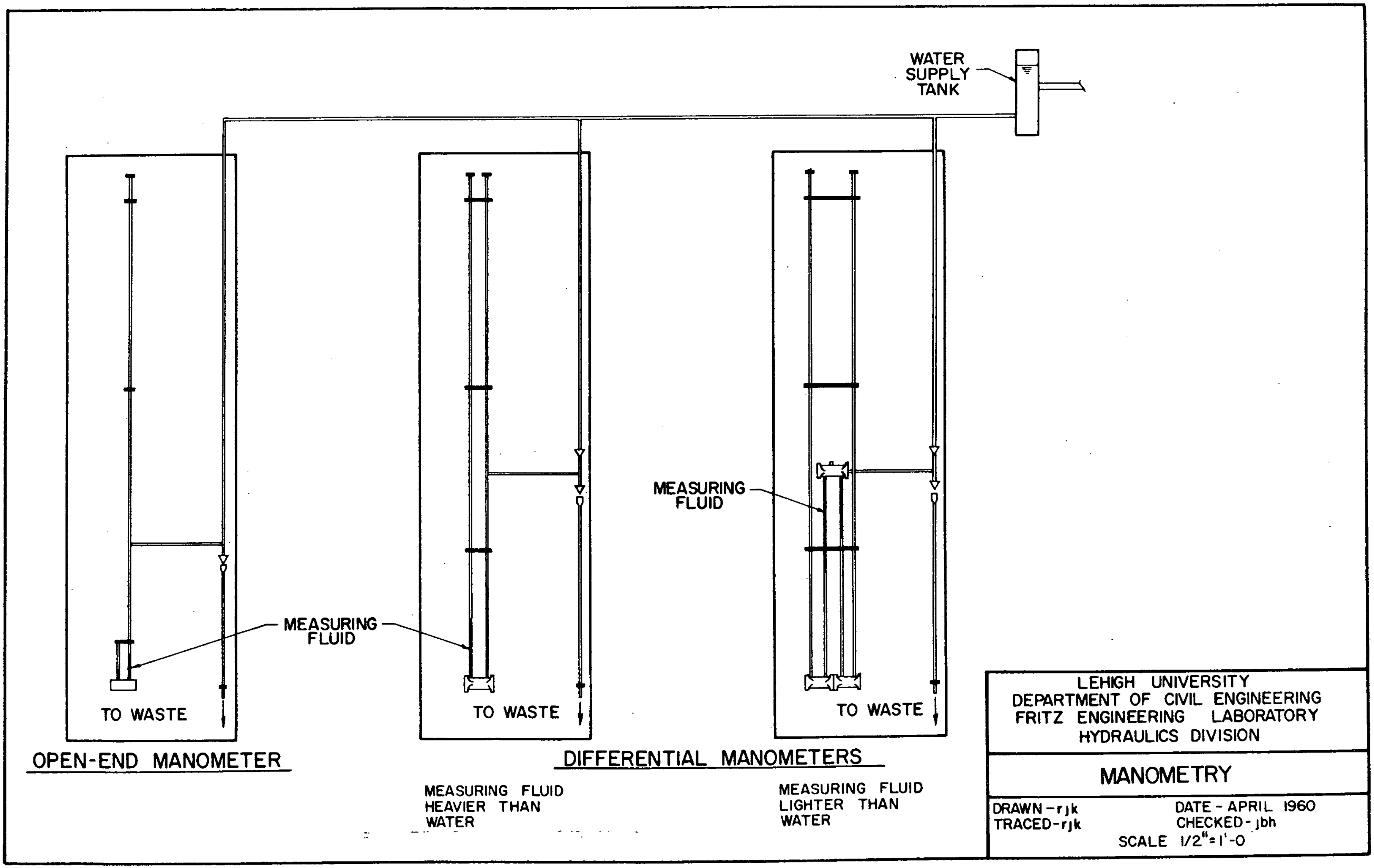
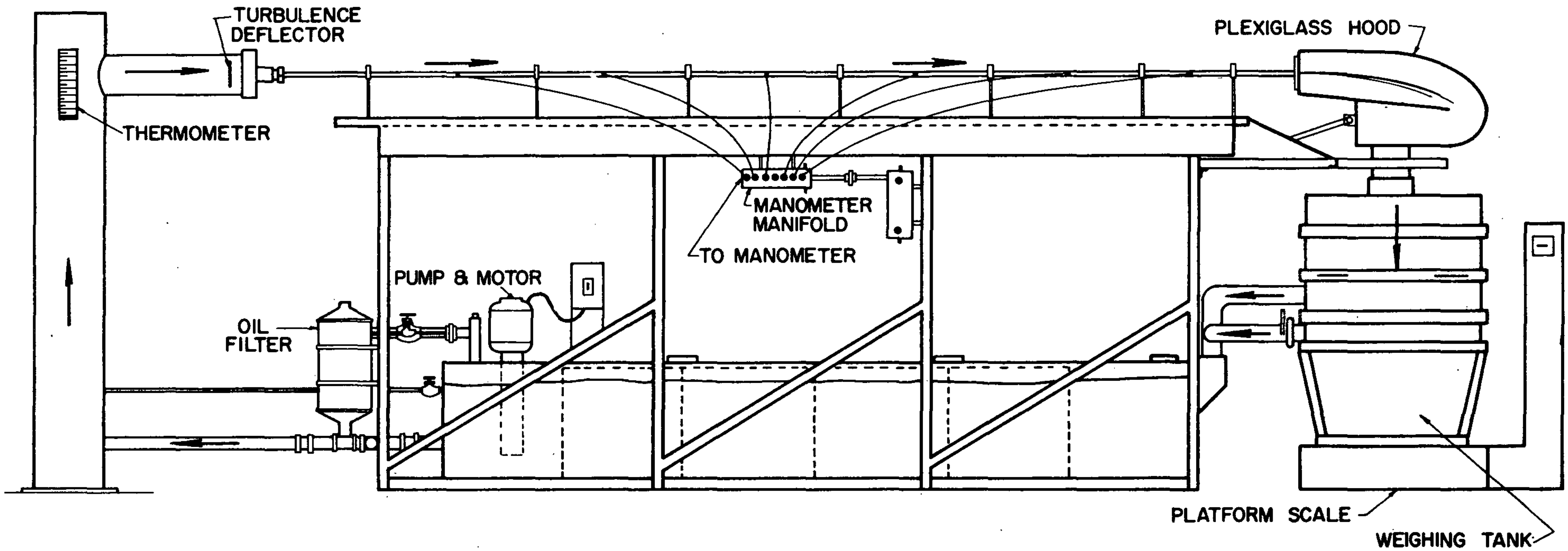

WATER
SUPPLY
TANK
MEASURING
FLUID
MEASURING
FLUID
TO WASTE
TO WASTE
TO WASTE
OPEN-END MANOMETER
DIFFERENTIAL MANOMETERS
MEASURING FLUID
HEAVIER THAN
WATER
MEASURING FLUID
LIGHTER THAN
WATER
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
MANOMETRY
DRAWN - rjk
TRACED - rjk
DATE - APRIL 1960
CHECKED - jbh
SCALE 1/2" = 1'-0

Figure 11

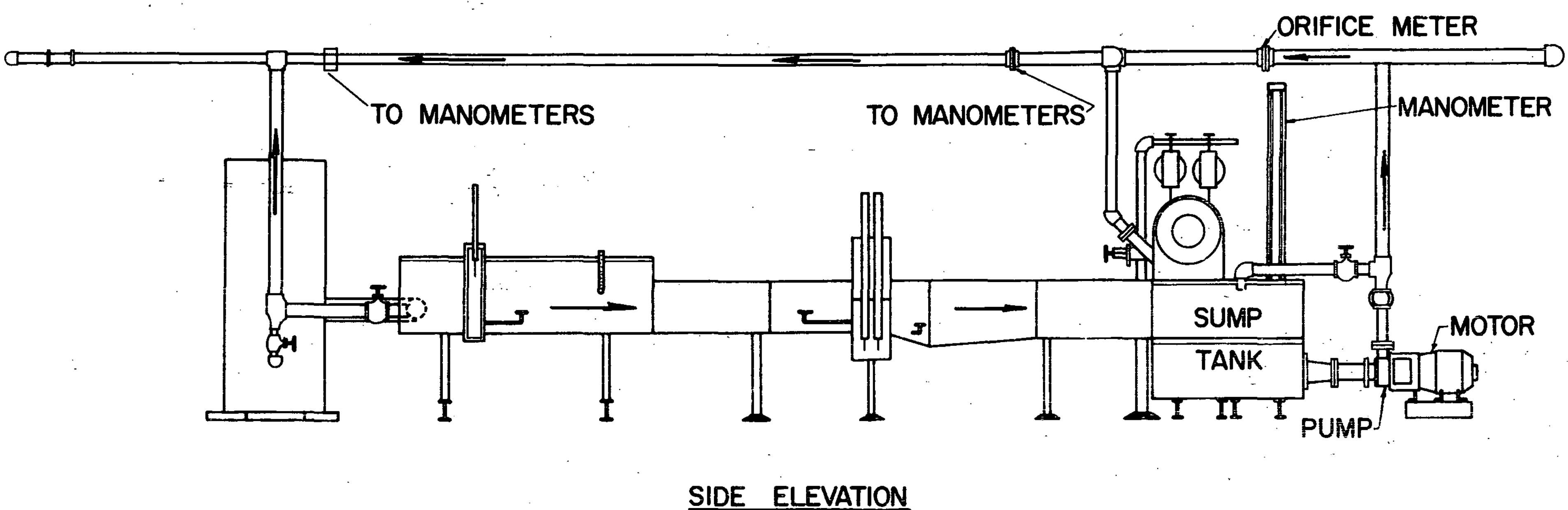


LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION

PIPE FRICTION
(REYNOLDS NUMBER BELOW 2000)

DRAWN - rjk   DATE - APRIL 1960
TRACED - rjk   CHECKED - jbh
SCALE 1/2" = 1'-0

Figure 12



LEHIGH UNIVERSITY DEPARTMENT OF CIVIL ENGINEERING FRITZ ENGINEERING LABORATORY HYDRAULICS DIVISION
PIPE FRICTION (REYNOLDS NUMBER ABOVE 2000)
DRAWN - rjk   DATE - APRIL 1960 TRACED - rjk   CHECKED - jbh SCALE 1/2" = 1'-0

Figure 13

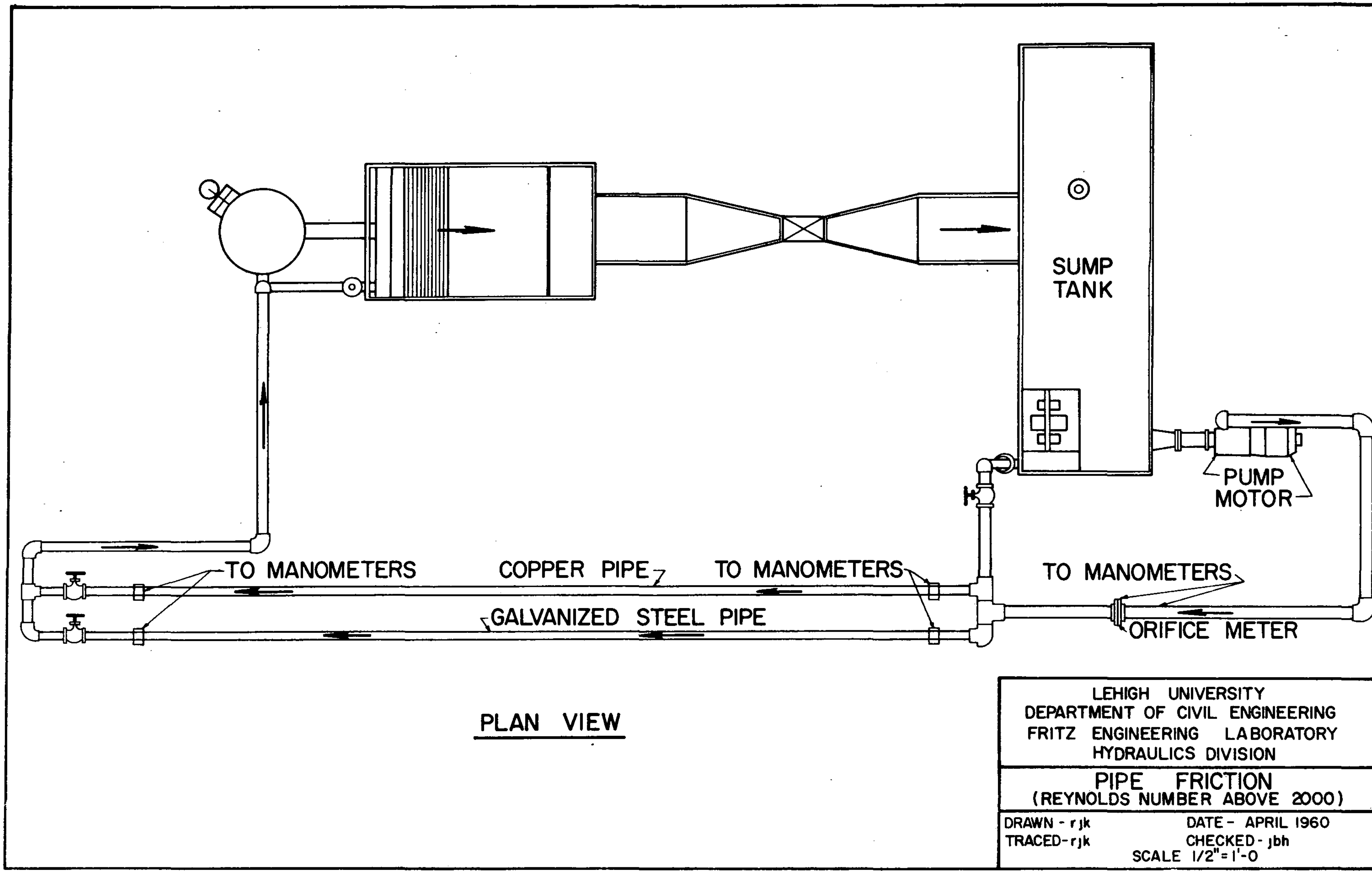

SUMP
TANK
PUMP
MOTOR
TO MANOMETERS
COPPER PIPE
TO MANOMETERS
TO MANOMETERS
GALVANIZED STEEL PIPE
ORIFICE METER
PLAN VIEW
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
PIPE FRICTION
(REYNOLDS NUMBER ABOVE 2000)
DRAWN - rjk
TRACED-rjk
DATE - APRIL 1960
CHECKED - jbh
SCALE 1/2"=1'-0

Figure 14

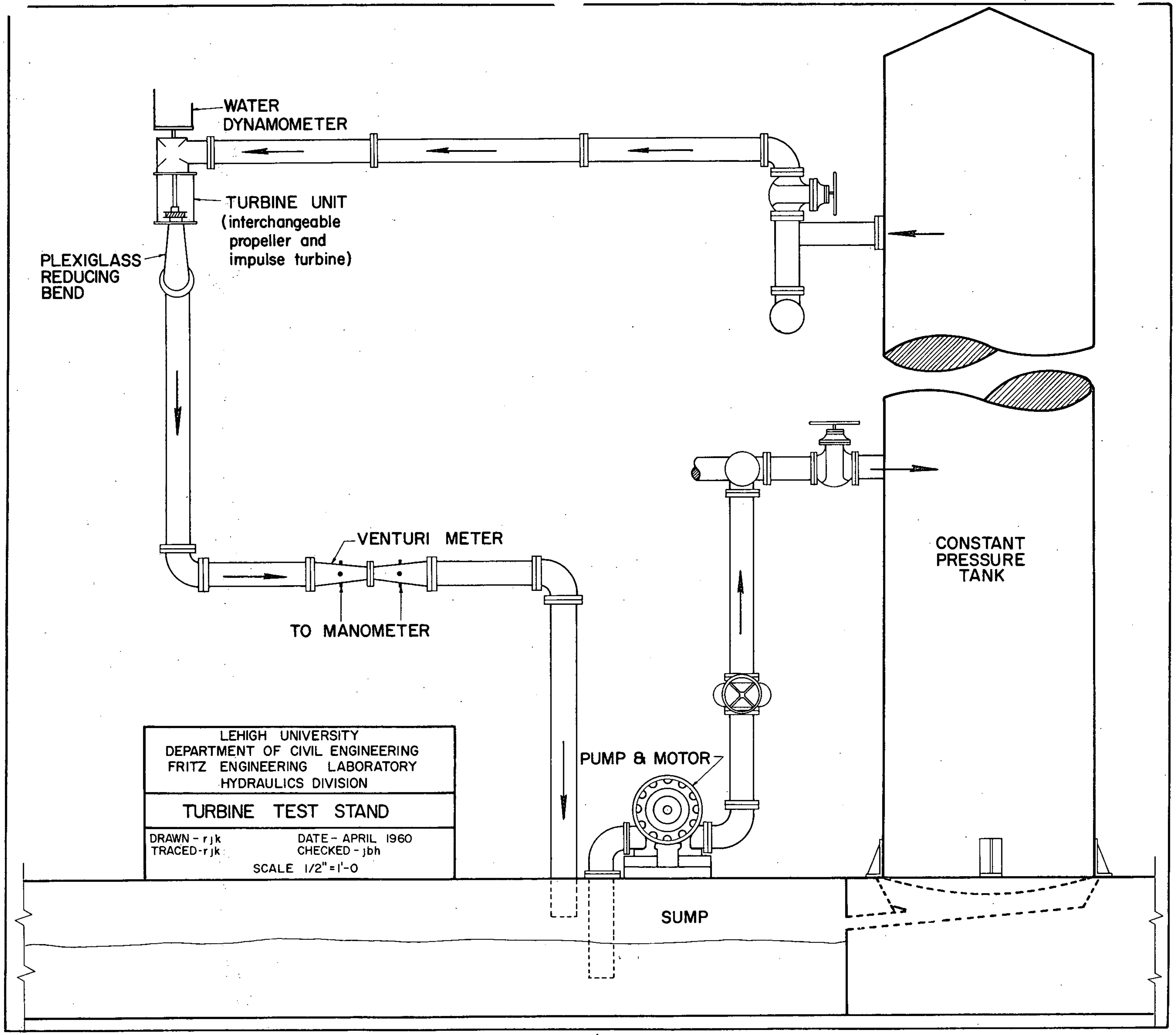

WATER DYNAMOMETER
TURBINE UNIT (interchangeable propeller and impulse turbine)
PLEXIGLASS REDUCING BEND
VENTURI METER
TO MANOMETER
CONSTANT PRESSURE TANK
PUMP & MOTOR
SUMP
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
TURBINE TEST STAND
DRAWN - rjk
TRACED-rjk
DATE - APRIL 1960
CHECKED - jbh
SCALE 1/2"=1'-0

Fig. 15

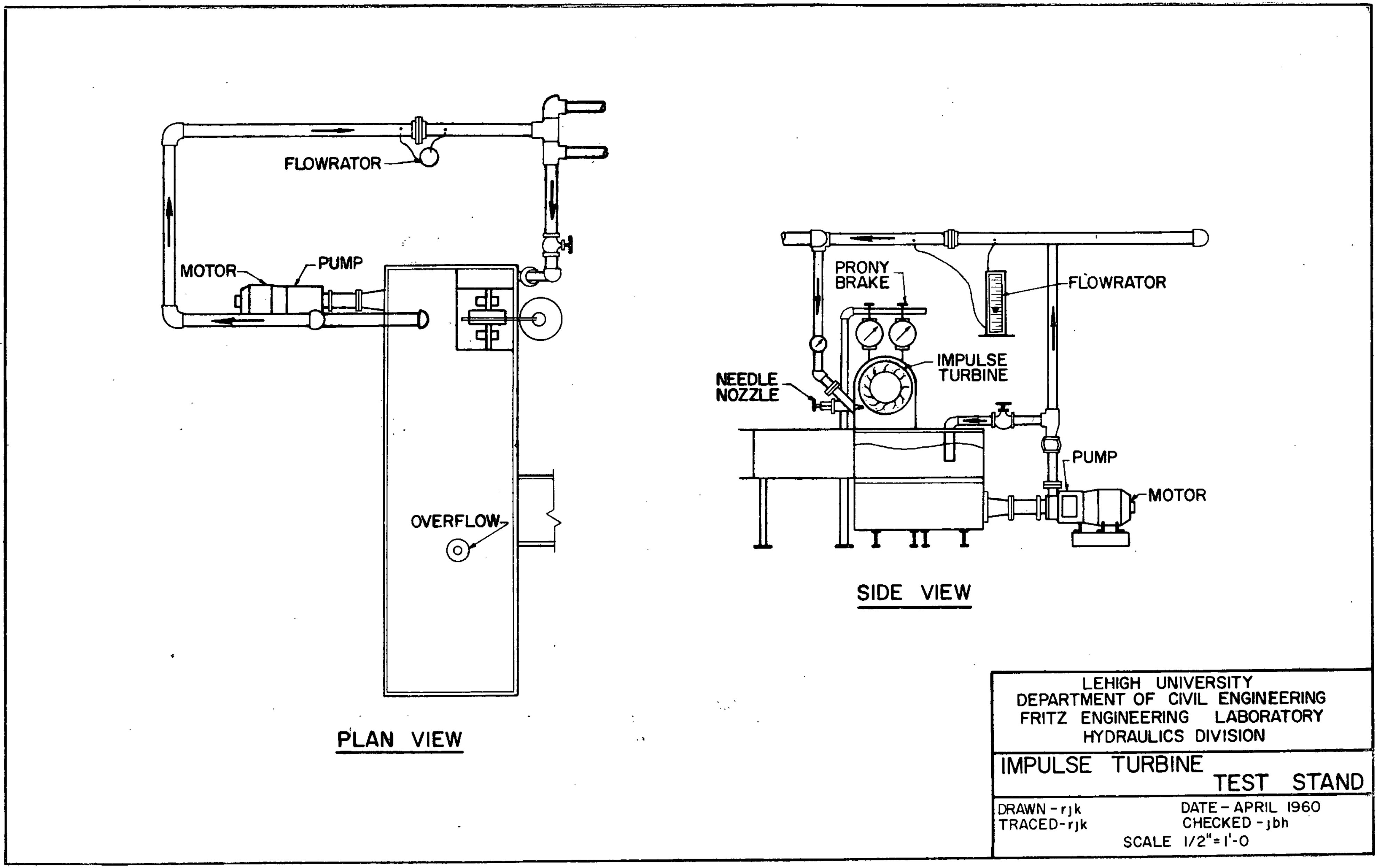

FLOWRATOR
MOTOR
PUMP
OVERFLOW
PLAN VIEW
PRONY BRAKE
FLOWRATOR
NEEDLE NOZZLE
IMPULSE TURBINE
PUMP
MOTOR
SIDE VIEW
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
IMPULSE TURBINE TEST STAND
DRAWN - rjk
TRACED - rjk
DATE - APRIL 1960
CHECKED - jbh
SCALE 1/2"=1'-0

Fig. 16

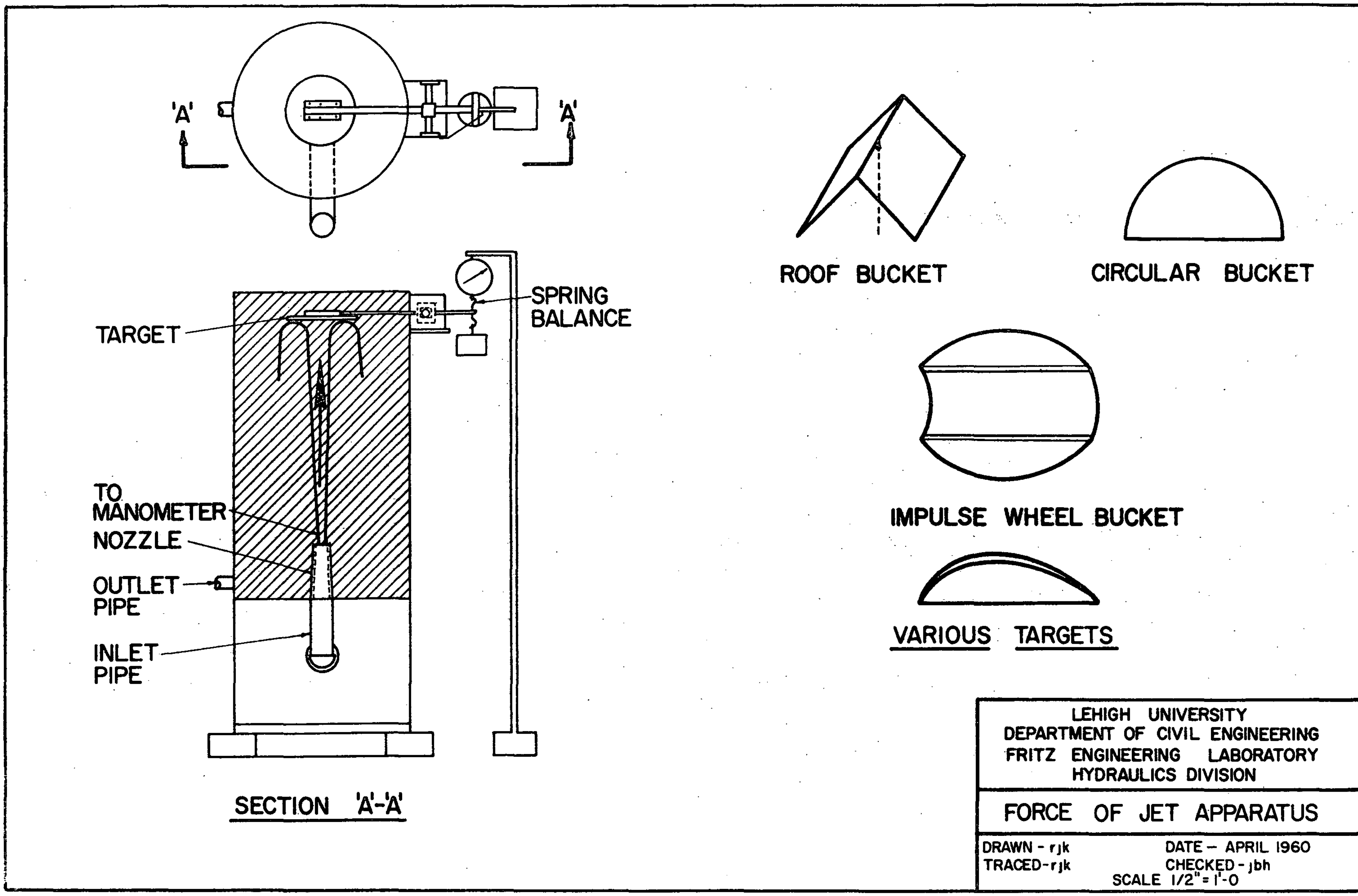

'A'
'A'
TARGET
SPRING
BALANCE
TO
MANOMETER
NOZZLE
OUTLET
PIPE
INLET
PIPE
SECTION 'A'-'A'
ROOF BUCKET
CIRCULAR BUCKET
IMPULSE WHEEL BUCKET
VARIOUS TARGETS
LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
FORCE OF JET APPARATUS
DRAWN - rjk
TRACED-rjk
DATE - APRIL 1960
CHECKED - jbh
SCALE 1/2"=1'-0

Figure 17

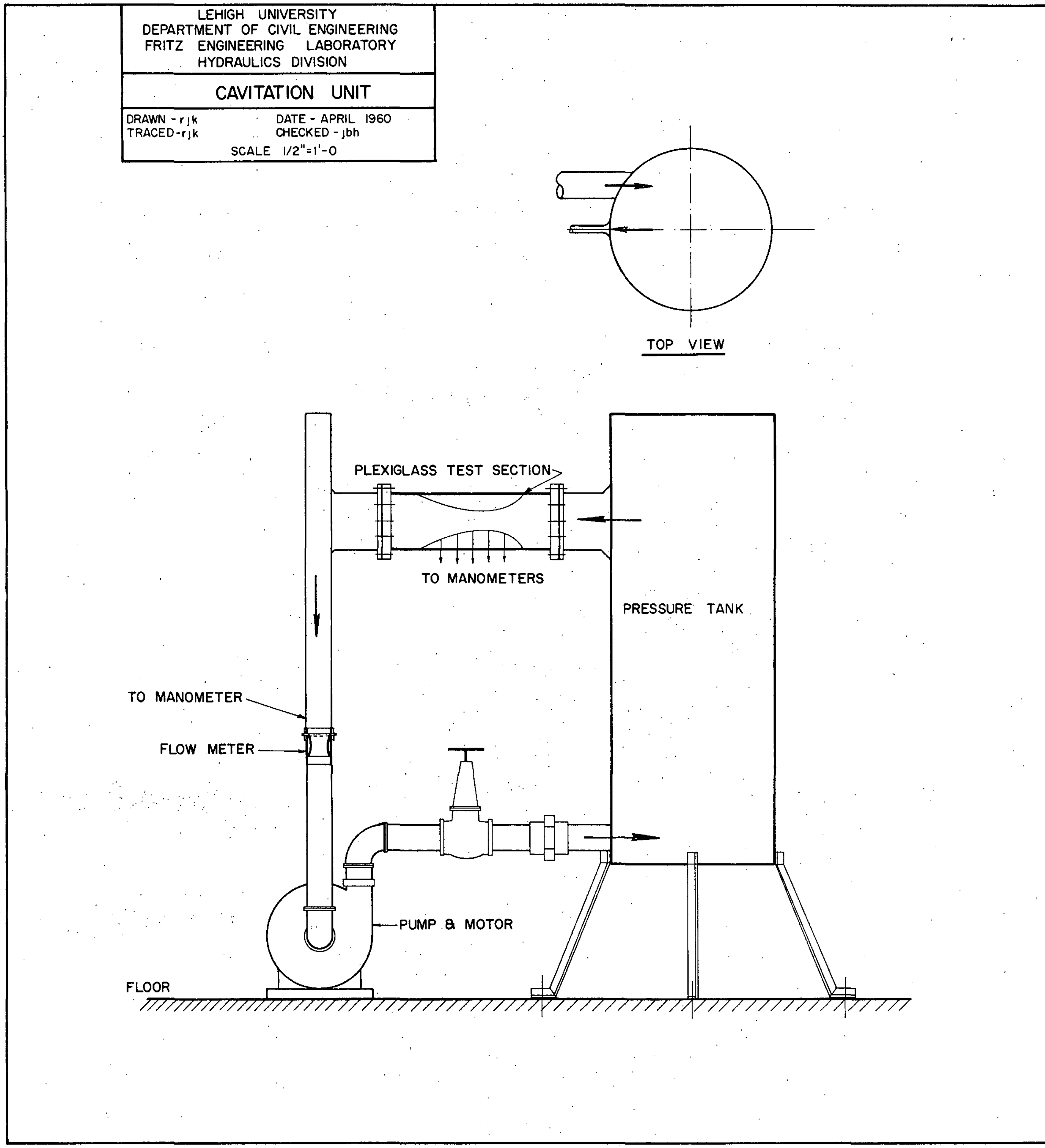

LEHIGH UNIVERSITY
DEPARTMENT OF CIVIL ENGINEERING
FRITZ ENGINEERING LABORATORY
HYDRAULICS DIVISION
CAVITATION UNIT
DRAWN - rjk
TRACED-rjk
DATE - APRIL 1960
CHECKED - jbh
SCALE 1/2"=1'-0
TOP VIEW
PLEXIGLASS TEST SECTION
TO MANOMETERS
PRESSURE TANK
TO MANOMETER
FLOW METER
PUMP & MOTOR
FLOOR

Fig. 18

APPENDIX A

LEHIGH UNIVERSITY
Department of Civil Engineering
Fritz Engineering Laboratory

HYDRAULICS DIVISION

COURSE OUTLINES

The numbers in brackets indicate the number of lectures or meetings per week.

For Undergraduates

C.E.121. MECHANICS OF FLUIDS (3)
The behavior of real fluids and the more important physical laws; potential flow, boundary layer, lift, drag, and waves, with practical applications to flow through pipes, open channels, turbines, and pumps. Dimensional analysis and similitude.

C.E.123. FLUID MECHANICS LABORATORY (1)
Introduction to laboratory techniques, calibration, principles, and fluid measurements. Closed conduit flow of water, oil, and air; open channel flow of water, wind tunnel studies; hydraulic machinery testing.

C.E.123. APPLIED HYDROLOGY (2)
The Hydrologic cycle. Flow measurement and interpretation of stream flow data. Frequency and Duration Studies. Hydrographs of runoff. Stream flow Routing. Applications of Hydrologic techniques with statistical analysis.

C.E.125. HYDRAULIC ENGINEERING (2)
Flow in pressure conduits in series, parallel and network arrangements; uniform and non-uniform flow in open channels; pumping; design of sanitary and storm sewage systems; consideration of engineering economy as applied to hydraulic projects.

Appendix A - Course Outlines

For Advanced Undergraduates and Graduates

C.E.320. HYDRAULIC ENGINEERING STRUCTURES (3)
Preparation and protection of foundations. Design of earth, gravity, arch, and buttressed dams. Wave forces. Design of seawalls, bulkheads and breakwaters.

C.E.321. WATER POWER AND PUMPING (3)
Theory of hydraulic turbines. Study of penstocks, scroll cases, draft tubes, water hammer and cavitation. Theory and design of pumps. Performance and testing of turbines and pumps.

C.E.322. HYDROMECHANICS (3)
Fundamental principles of fluid motion, with emphasis on hydraulic applications. Euler's, Bernoulli's, and Laplace's equations, gradually varied open channel flow, wave motion, water hammer, sediment transportation, and cavitation.

For Graduates

C.E.407. THESIS (1-6)

C.E.420. HYDROLOGY AND OPEN CHANNEL FLOW (3)
Components of the hydrologic cycle. Analysis and prediction of basic quantities required for hydraulic engineering design and storage requirements. Non-uniform flow in open channels and reservoirs, backwater curves in natural and artificial channels, hydraulic jump, surges and waves, standing waves in supercritical flow. Transportation of sediment. Supervised problems.

C.E.421 HYDRAULIC LABORATORY PRACTICE (2-5)
Study of theory and method of hydraulic experimentation simultaneously with laboratory work.

C.E.422. HYDRAULIC RESEARCH (2-5)
Individual research problems with reports.

C.E.423. ADVANCED HYDRAULIC ENGINEERING
and HYDROMECHANICS (3)
Principles of irrotational flow. Laminar motion. Turbulence. Boundary layer. Air entrainment. Wave motion. Flow through non-prismatic channels. Rapidly varied unsteady flow.

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STAFF PUBLICATIONS

McPherson, M.B.	DESIGN OF DAM OUTLET TRASH-RACK VERIFIED BY MODEL TESTS Civil Engineering	Aug. 1950
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